10/030913

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
REQUEST FOR FILING NATIONAL PHASE OF
PCT APPLICATION UNDER 35 U.S.C. 371 AND 37 CFR 1.494 OR 1.495

To: Hon. Commissioner of Patents
Washington, D.C. 20231

JC05 Rec'd PCT/PTO 14 JAN 2002
00909

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

Atty Dkt: P 290591 /E23223 JFL
M# /Client Ref.

From: Pillsbury Winthrop LLP, IP Group:

Date: January 14, 2002

This is a **REQUEST** for **FILING** a PCT/USA National Phase Application based on:

1. International Application	2. International Filing Date	3. Earliest Priority Date Claimed
PCT/NO00/00235	10 July 2000	13 July 1999
⇧ country code	Day MONTH Year	Day MONTH Year (use item 2 if no earlier priority)

4. Measured from the earliest priority date in item 3, this PCT/USA National Phase Application Request is being filed within:

   (a) ☐ 20 months from above item 3 date (b) ☒ 30 months from above item 3 date,

   (c) Therefore, the due date (unextendable) is January 13, 2002

5. Title of Invention SYSTEM FOR SCANNING OF THE GEOMETRY OF LARGE OBJECTS

6. Inventor(s) Alf PETTERSEN

Applicant herewith submits the following under 35 U.S.C. 371 to effect filing:

7. ☒ Please immediately start national examination procedures (35 U.S.C. 371 (f)).

8. ☐ **A copy of the International Application** as filed (35 U.S.C. 371(c)(2)) is transmitted herewith (file if in English but, if in foreign language, file only if not transmitted to PTO by the International Bureau) including:

   a. ☐ Request;
   b. ☐ Abstract;
   c. ___ pgs. Spec. and Claims;
   d. ___ sheet(s) Drawing which are ☐ informal ☐ formal of size ☐ A4 ☐ 11"

9. ☒ **A copy of the International Application has been transmitted by the International Bureau.**

10. **A translation of the International Application** into English (35 U.S.C. 371(c)(2))
    a. ☒ Is transmitted herewith including: (1) ☐ Request; (2) ☒ Abstract;
       (3) 7 pgs. Spec. and Claims;
       (4) 2 sheet(s) Drawing which are:
       ☐ informal ☒ formal of size ☒ A4 ☐ 11"
    b. ☐ Is not required, as the application was filed in English.
    c. ☐ Is not herewith, but will be filed when required by the forthcoming PTO Missing Requirements Notice per Rule 494(c) if box 4(a) is X'd or Rule 495(c) if box 4(b) is X'd.
    d. ☐ Translation verification attached (not required now).

RE: USA National Phase Filing of PCT /NO00/00235

JC13 Rec'd PCT/PTO 14 JAN 2002

11. ☒ Please see the attached Preliminary Amendment

12. ☐ Amendments to the claims of the International Application **under PCT Article 19 (35 U.S.C. 371(c)(3)), i.e., before 18th month from first priority date above in item 3, are transmitted herewith (file only if in English) including:**

13. ☒ PCT Article 19 claim amendments (if any) have been transmitted by the International Bureau

14. ☐ Translation of the amendments to the claims **under PCT Article 19 (35 U.S.C. 371(c)(3)), i.e., of claim amendments** made before 18th month, **is attached (required by 20th month from the date in item 3 if box 4(a) above is X'd, or 30th month if box 4(b) is X'd, or else amendments will be considered canceled).**

15. **A declaration of the inventor** (35 U.S.C. 371(c)(4))
a. ☐ is submitted herewith ☐ Original ☐ Facsimile/Copy
b. ☒ is not herewith, but will be filed when required by the forthcoming PTO Missing Requirements Notice per Rule 494(c) if box 4(a) is X'd or Rule 495(c) if box 4(b) is X'd.

16. **An International Search Report (ISR):**
a. Was prepared by ☐ European Patent Office ☐ Japanese Patent Office ☒ Other
b. ☒ Has been transmitted by the international Bureau to PTO.
c. ☒ Copy herewith (3 pg(s).) ☒ plus Annex of family members (1 pg(s).).

17. **International Preliminary Examination Report** (IPER):
a. ☒ Has been transmitted (if this letter is filed after 28 months from date in item 3) in English by the International Bureau with Annexes (if any) in original language.
b. ☒ copy herewith in English.
c.1 ☐ IPER Annex(es) in original language ("Annexes" are amendments made to claims/spec/drawings during Examination) including attached amended:
c.2 ☐ Specification/claim pages #__ claims #
Dwg Sheets #
d. ☐ Translation of Annex(es) to IPER **(required by 30th month due date, or else annexed amendments will be considered canceled).**

18. **Information Disclosure Statement** including:
a. ☒ Attached Form PTO-1449 listing documents
b. ☒ Attached copies of documents listed on Form PTO-1449
c. ☒ A concise explanation of relevance of ISR references is given in the ISR.

19. ☐ **Assignment** document and Cover Sheet for recording are attached. Please mail the recorded assignment document back to the person whose signature, name and address appear at the end of this letter.

20. ☐ Copy of Power to IA agent.

21. ☒ **Drawings** (complete only if 8d or 10a(4) not completed): 2 sheet(s) per set: ☐ 1 set informal; ☒ Formal of size ☒ A4 ☐ 11"

22. Small Entity Status ☐ is **Not** claimed ☒ is claimed (**pre-filing confirmation required**)
22(a) ___ (No.) Small Entity Statement(s) enclosed (since 9/8/00 Small Entity Statements(s) not essential to make claim)

23. **Priority** is hereby claimed under 35 U.S.C. 119/365 based on the priority claim and the certified copy, both filed in the International Application during the international stage based on the filing in (country) NO of:

	Application No.	Filing Date		Application No.	Filing Date
(1)	19993446	13 July 1999	(2)		
(3)			(4)		
(5)			(6)		

a. ☒ See Form PCT/IB/304 sent to US/DO with copy of priority documents. If copy has not been received, please proceed promptly to obtain same from the IB.
b. ☒ Copy of Form PCT/IB/304 attached.

RE: USA National Phase Filing of PCT/NO00/00235

24. Attached: 10/8/01 Response to Written Opinion and Replacement Claims 1-12

25 Per Item 17.c2, **cancel original** pages #___, claims #___, Drawing Sheets #

26. **Calculation of the U.S. National Fee (35 U.S.C. 371 (c)(1)) and other fees is as follows:**
Based on amended claim(s) per above item(s) ☐ 12, ☐ 14, ☒ 17, ☐ 25 (hilite)

Total Effective Claims	10	minus 20 =	0	x $18/$9	=	$0	966/967
Independent Claims	2	minus 3 =	0	x $84/$42	=	$0	964/965
If any proper (ignore improper) Multiple Dependent claim is present,				add$280/$140		+0	968/969

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(4)): →→ **BASIC FEE REQUIRED, NOW** →→→→

A. If country code letters in item 1 are **not** "US","BR","BB","TT","MX","IL" "NZ", "IN" or "ZA"

See item 16 re:
1. Search Report was not prepared by EPO or JPO - - - - - - - - - add$1,040/$520 — 960/961
2. Search Report was prepared by EPO or JPO - - - - - - - - - - - - add$890/$445 — +520 — 970/971

SKIP B, C, D AND E UNLESS country code letters in item 1 are "US","BR","BB","TT","MX","IL", "NZ", "IN", "ZA", "LC" or "PH"

(X) (only) (one) (of) (these) (4) (boxes)

☒ B. If USPTO did not issue both International Search Report (ISR) and (if box 4(b) above is X'd) the International Examination Report (IPER), - - - - - - - - - - - - - - - - - - - add$1,040/$520 — + — 960/961

☐ C. If USPTO issued ISR but not IPER (or box 4(a) above is X'd), - add$740/$370 — +0 — 958/959

☐ D. If USPTO issued IPER but IPER Sec. V boxes not all 3 YES, - add$710/$355 — +0 — 956/957

☐ E. If international preliminary examination fee was paid to USPTO and Rules 492(a)(4) and 496(b) satisfied (in IPER Sec. V all 3 boxes must be YES for all claims), - - add $100/$50 — +0 — 962/963

27. **SUBTOTAL =** ~~$1,040~~ 520.00

28. If Assignment box 19 above is X'd, add Assignment Recording fee of ----$40 — +0 — (581)

29. If box 15a is x'd, determine whether inventorship on Declaration is different than in international stage. If yes, add (per Rule 497(d) ----$130 — +0 — (098)

30. Attached is a check to cover the - **TOTAL FEES** ~~$1,040~~ 520.00

Our Deposit Account No. 03-3975
Our Order No. 12199 (C#) | 290591 (M#)

00909

CHARGE STATEMENT: The Commissioner is hereby authorized to charge any fee specifically authorized hereafter, or any missing or insufficient fee(s) filed, or asserted to be filed, or which should have been filed herewith or concerning any paper filed hereafter, and which may be required under Rules 16-18 and 492 (missing or insufficient fee only) now or hereafter relative to this application and the resulting Official document under Rule 20, or credit any overpayment, to our Account/Order Nos. shown above for which purpose a duplicate copy of this sheet is attached.
This CHARGE STATEMENT does not authorize charge of the issue fee until/unless an issue fee transmittal form is filed

Pillsbury Winthrop LLP
Intellectual Property Group
By Atty: Paul T. Bowen **Reg. No.** 38009
Sig: Paul Bowen **Fax:** (703) 905-2500
Atty/Sec: PTB/jck **Tel:** (703) 905-2020

NOTE: File in duplicate with 2 postcard receipts (PAT-103) & attachments.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re PATENT APPLICATION OF

Inventor(s): PETTERSEN

Filed: Herewith

Title: SYSTEM FOR SCANNING OF THE GEOMETRY OF LARGE OBJECTS

January 14, 2002

PRELIMINARY AMENDMENT

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Please amend this application as follows:

IN THE SPECIFICATION:

At the top of the first page, just under the title, insert

☒ --This application is the National Phase of International Application PCT/NO00/00235 filed July 10, 2000 which designated the U.S. and that International Application

☒ was ☐ was not published under PCT Article 21(2) in English.—

IN THE CLAIMS:

Please amend claims 1-12, as follows:

1. (Amended) System for detection of the surface geometry of an object, comprising a sensor unit with apparatus for local, point by point detection of surface geometry, and a robot unit for moving the sensor unit, wherein the sensor unit includes an optical scanner unit for non-touch probing and detection of the surface geometry of the object, and a position measuring unit including a camera-based sensor designed for registering an image of a network including reference points in known positions and for determining the position of the

sensor unit in a global coordinate system defined by said network of reference points, and wherein a computing unit is provided and designed for collection of data from the scanner unit and the position measuring unit and for transformation of the data from the scanner unit to relate them to the global coordinate system.

2. (Amended) System as defined in claim 1, wherein the robot unit is designed for stepwise movement of the sensor unit.

3. (Amended) System as defined in claim 1, wherein the network of reference points is on the object, and the position for each reference point in the network is known relative to a coordinate system related to the object.

4. (Amended) System as defined in claim 1, wherein the robot unit is designed to move the sensor unit step-wise over the object.

5. (Amended) System as defined in claim 1, wherein the scanner unit is chosen from the following group: laser scanner, single-point distance meter, laser-based triangulation sensor combined with camera, triangulation sensor with two-axis scanning laser, triangulation sensor with laser raster projection in combination with camera, sensor based on pattern projection combined with at least one camera.

6. (Amended) System as defined in claim 1, wherein the robot unit is chosen from the following group: arm-based robot, Cartesian robot, robot with one, two or more degrees of freedom, program controlled robot, real-time position-controlled robot based on registered position of the sensor unit in relation to the object and instruction for movement relative to current position.

7. (Twice Amended) System as described in claim 1, wherein said camera in the unit for measuring position is a CCD camera.

8. (Twice Amended) System as described in claim 3, wherein the reference points are holes or depressions in the surface of the object.

9. (Twice Amended) System as described in claim 3, wherein the reference points include targets placed on the object or in the mentioned holes or depressions in the surface of the object.

10. (Amended) Method for detection of the surface geometry of an object, including use of a sensor unit comprising apparatus for local, point by point detection of the surface geometry, a position measuring unit to determine the position of the sensor unit in relation to a network of reference points in known positions relative to a global coordinate system, and a robot unit for moving the sensor unit, the method comprising:

positioning the sensor unit such that a region of the surface of the object is inside a measurement volume of the apparatus,

optically scanning said region by means of said apparatus;

determining by means of said position measuring unit simultaneously the position of the optical scanning apparatus relative to the coordinate system of the network, and

transferring data from the scanning apparatus to a computing unit where said data are transformed to the coordinate system of the network and stored.

11. (Amended) Method as specified in claim 10, wherein the robot unit moves the sensor unit in stepwise fashion.

12. (Amended) Method for calibration of a sensor unit which comprises apparatus for local detection of a surface geometry, and a position measuring unit to determine the position of the sensor unit in a global coordinate system relative to a network of reference points in known positions, and where the sensor unit is mounted on a robot unit for movement relative to an object, the method comprising:

a) positioning the sensor unit such that at least one of the reference points is inside a measurement volume of the apparatus, said apparatus capable of optical scanning,

b) determining the position of the reference point relative to the optical scanning apparatus,

c) determining by means of the position measuring unit simultaneously the position of the sensor unit relative to the coordinate system of the network,

d) repeating steps a-c or b, c until the positions of at least three reference points have been determined relative to the coordinate system of the optical scanning apparatus, and

e) calculating a transformation matrix based on data registered by the scanning apparatus and the position measuring unit to describe the mutual relationship.

See attached Appendix for the changes made to effect the above claims.

<u>REMARKS</u>

Claims 1-12, as amended, are pending herein. Claims 1-12 have been amended to eliminate multiple dependency and to place the claims in better conformance with U.S. practice.

Attached hereto is a marked-up version of the changes made to the specification and claims by the current amendment. The attached Appendix is captioned **<u>"Version with markings to show changes made"</u>**.

Prompt and favorable consideration is respectfully requested.

Respectfully submitted,

PILLSBURY WINTHROP LLP
Intellectual Property Group

By: [signature]
Attorney: Paul T. Bowen
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PTB/jck
Attachment:
Appendix

1600 Tysons Boulevard
McLean, VA 22102
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APPENDIX

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

At the top of the first page, just under the title, insert

☒ --This application is the National Phase of International Application PCT/NO00/00235 filed July 10, 2000 which designated the U.S. and that International Application

☐ was ☒ was not published under PCT Article 21(2) in English.—

IN THE CLAIMS:

Please amend claims 1-12, as follows:

1. (Amended) System for detection of the surface geometry of an object [(6)], comprising a sensor unit [(1)] with apparatus [(2)] for local, point by point detection of surface geometry, and a robot unit [(4)] for moving the sensor unit [(1)], [characterized in that] wherein the sensor unit [(1)] includes an optical scanner unit [(2)] for non-touch probing and detection of the surface geometry of the object, and a position measuring unit [(3) consisting of] including a camera-based sensor [(7)] designed for registering an image of a network [(8) consisting of] including reference points [(9)] in known positions and for determining the position of the sensor unit [(1)] in a global coordinate system defined by said network [(8)] of reference points [(9)], and [that] wherein a computing unit [(5)] is provided and designed for collection of data from the scanner unit [(2)] and the position measuring unit [(3)] and for transformation of the data from the scanner unit [(2)] to relate them to the global coordinate system.

2. (Amended) System as defined in claim 1, [characterized in that] wherein the robot unit [(4)] is designed for stepwise movement of the sensor unit [(1)].

3. (Amended) System as defined in claim 1, [characterized in that] wherein the network [(8)] of reference points [(9)] is on the object, and [that] the position for each reference point in the network is known relative to a coordinate system related to the object.

4. (Amended) System as defined in claim 1, [characterized in that] wherein the robot unit [(4)] is designed to move the sensor unit [(1)] step-wise over the object [(6)].

5. (Amended) System as defined in [one or more of the preceding claims] claim 1, [characterized in that] wherein the scanner unit [(2)] is chosen from the following group: laser scanner, single-point distance meter, laser-based triangulation sensor combined with camera, triangulation sensor with two-axis scanning laser, triangulation sensor with laser raster projection in combination with camera, sensor based on pattern projection combined with at least one camera.

6. (Amended) System as defined in [one or more of the preceding claims] claim 1, [characterized in that] wherein the robot unit [(4)] is chosen from the following group: arm-based robot, Cartesian robot, robot with one, two or more degrees of freedom, program controlled robot, real-time position-controlled robot based on registered position of the sensor unit [(1)] in relation to the object and instruction for movement relative to current position.

7. (Amended) System as described in [one or more of the preceding claims] claim 1, [characterized in that] wherein said camera in the unit [(3)] for measuring position is a CCD camera.

8. (Amended) System as described in claim 3, [characterized in that] wherein the reference points [(9)] are holes or depressions in the surface of the object [(6)].

9. (Amended) System as described in claim 3 [or 8], [characterized in that] <u>wherein</u> the reference points [(9) consist of so-called "targets"] <u>include targets</u> placed on the object [(6)] or in the mentioned holes or depressions in the surface of the object [(6)].

10. (Amended) Method for detection of the surface geometry of an object [(6)], including use of a sensor unit [(1)] comprising apparatus [(2)] for local, point by point detection of the surface geometry, a position measuring unit [(3)] to determine the position of the sensor unit in relation to a network [(8)] of reference points [(9)] in known positions relative to a global coordinate system, and a robot unit for moving the sensor unit, [characterized in the steps of] <u>the method comprising</u>:

positioning the sensor unit [(1)] such that a region of the surface of the object [(6)] is inside a measurement volume of the apparatus [(2)],

optically scanning said region by means of said apparatus [(2)];

determining by means of said position measuring unit [(3)] simultaneously the position of the optical scanning apparatus [(2)] relative to the coordinate system of the network [(8)], and

transferring data from the scanning apparatus [(2)] to a computing unit [(5)] where said data are transformed to the coordinate system of the network [(8)] and stored.

11. (Amended) Method as specified in claim 10, [characterized in stepwise moving of] <u>wherein the robot unit moves</u> the sensor unit [(1) by means of the robot unit (4)] <u>in stepwise fashion</u>.

12. (Amended) Method for calibration of a sensor unit [(1)] which comprises apparatus [(2)] for local detection of a surface geometry, and a position measuring unit [(3)] to determine the position of the sensor unit in a global coordinate system relative to a network [(8)] of reference points [(9)] in known positions, and where the sensor unit [(1)] is mounted

on a robot unit [(4)] for movement relative to an object [(6)], [characterized in the steps of] the method comprising:

a) positioning the sensor unit [(1)] such that at least one of the reference points [(9)] is inside a measurement volume of the apparatus [(2)], said apparatus capable of optical scanning,

b) determining the position of the reference point [(9)] relative to the optical scanning apparatus [(2)],

c) determining by means of the position measuring unit [(3)] simultaneously the position of the sensor unit [(1)] relative to the coordinate system of the network [(8)],

d) repeating steps a-c or b, c until the [position] positions of at least three reference points [(9)] have been determined relative to the coordinate system of the optical scanning apparatus, and

e) calculating a transformation matrix based on data registered by the scanning apparatus [(2)] and the position measuring unit [(3)] to describe the mutual relationship.

SYSTEM FOR SCANNING OF THE GEOMETRY OF LARGE OBJECTS

The present invention relates to a system as well as a method to scan the geometry of objects as described in the introduction to claims 1 and 11.

A number of laser based scanners for measurement of surfaces exist. These are characterized by having a limited working volume, or limited measurement volume, requiring a specific offset from the surface, and requiring a specific orientation relative to the surface. Scanners are therefore often mounted on accurate coordinate measurement machines, such that the scanner can be moved step-wise across the surface to scan region after region. A coordinate measurement machine is complex, inflexible and costly.

There is a need for more flexible, portable solutions. An alternative is attaching a scanner to a robot, in such a way that the robot moves the scanner across the object. For each position, a part of the surface is scanned. This measurement is registered relative to the position of the scanner, and is transformed to a global coordinate system provided by the robot.

Most robots have low accuracy. Transformation of the data based on the robot's coordinate system will therefore not produce a sufficiently accurate description of the object's total geometry. Calibration of the robot to better describe its movements will help, but due to effects like wear and temperature variations, this is still not good enough.

The present invention combines a solution comprising a robot and scanner with use of a position measuring device as described in Norwegian Patent No. 303.595. The scanner and the position measuring device are integrated into one sensor unit. In this solution, the position measuring device provides information on the exact position of the scanner. The robot is only used to move the sensor unit.

The characteristic features of the system and method are set forth in claims 1 and 11, respectively further embodiments are set forth in the dependent claims.

Figure 1 shows the system solution.

Figure 2 shows an alternative configuration.

Figure 3 shows as an example a scanner unit, a triangulation sensor.

Figure 4 shows an example of a position measuring device as described in Norwegian patent No. 303.595.

Figure 5 shows a method for determining the internal geometry of the sensor unit.

Figure 1 shows an example of a configuration of the system. It consists of principally two units, a sensor 1 and a robot 4. The robot is used to position the sensor in relation to the current area 12 on the object 6. The sensor 1 registers the local geometry of the object, and measures its own position relative to a global coordinate system 13.

The sensor unit 1 consists of a scanner unit 2 for local scanning of geometry plus position measuring unit 3 to determine the sensor unit's own position relative to the global coordinate system 13. The scanner unit 2, e.g. a laser scanner, emits a laser beam 11 which scans a limited region 12. The position measuring unit 3 registers its own position, and thereby the position of the sensor unit 1, relative to a network 8 of reference points 9. The positions of the reference points are known relative to the global coordinate system 13.

The system also includes a computing unit 5 which collects the data from scanner unit 2 and position measuring unit 3 and transforms all information from the scanner unit to the same global coordinate system 13. The computing unit 5 also sends data to the robot 4 to control the robot's movement relative to the object.

Figure 2 shows an alternative configuration. The reference points 9 are attached to the object 6. The position measuring unit 3 is placed to view these reference points.

The scanner unit 2 can e.g. be one of the following types, but is not limited to this:

- Laser distance meter which measures the distance between the scanner unit and the object in a single point,
- Triangulation sensor based on single-axis scanning laser or laser line projection combined with camera (e.g. CCD sensor). Such a sensor scans one line from each sensor position.
- Triangulation sensor based on dual-axis scanning laser or laser raster projection combined with camera (e.g. CCD sensor).

- Sensor based on projection of pattern combined with one or more cameras (e.g. CCD sensor).

Figure 3 shows the principle for a triangulation sensor. It contains a laser 14 which emits a laser beam 11 or a laser plane (line projection). The laser projects a point 15 or a line on the object 6. The point 15 is imaged through a lens 16 onto a sensor 17, e.g. a CCD array. The scanner unit 2 is calibrated in such a way that it measures the position of the point 15 relative to an internal coordinate system 18. In an alternative implementation, the laser beam can be aimed at the surface through a two-axis, movable mirror. In this way, a region of the surface can be scanned from each position of the triangulating sensor.

The significant characteristic of the scanner is that it registers the local geometry of an object relative to the internal coordinate system of the scanner. For each scanner position, a registration can be made of a point, points along a line, or points in a two-dimensional pattern.

In a preferred embodiment the position measuring device 3 is of a type described in Norwegian patent No. 303.595, as shown in figure 4. Essentially, this comprises one or more cameras mounted together in a unit. Each camera sees a reference pattern in the form of points, lines or other easily recognizable objects. For each position of the sensor unit 1, the points 9 in the reference pattern 8 are imaged through the lens 19 onto the sensor 20. The data is transferred to the computing unit 5. Software in the computing unit calculates the position and orientation of the position measuring unit 3 relative to the reference pattern 8. The position measuring device in figure 4 is shown with carrying handle 21 and activation switch 22 for manual operation. Also shown is an illumination source 23 for illumination of the reference pattern 8, and a mechanical probe 24 for point by point measurement by touching an object, as described in Norwegian patent No. 303.595.

It will be advantageous if the reference pattern 8 is known in the coordinate system of the object, or is a part of the object itself as depicted in figure 2. This can be achieved if the object has holes that can be recognized by the position measuring device, or if the reference pattern is attached to the object, e.g. by mounting easily recognizable targets into holes or depressions in the object. These targets may e.g. be purely passive markers, light sources, light reflectors or similar.

It is significant that the geometrical relationship between the scanner unit 2 and the unit 3 for measuring position be known and stable. This can partly be achieved through a stable, precise and known mechanical construction, and through separate calibration as described below.

The sole purpose of the robot 4 is to position the sensor unit 1 in the correct position and orientation relative to the object 6. Several types of robot principles may be used, e.g. arm robots, Cartesian robots, and robots with one, two, three or more degrees of freedom. The robot may be controlled by a predefined program, or by using the measured position of the sensor unit relative to the object and feed the robot instructions for relative movement in relation to the current position.

For each position, the data from sensor unit 1 must be evaluated in the same global coordinate system 13. This requires that the relationship between the coordinate system X_S, Y_S, Z_S, of the scanner unit and the coordinate system of the unit for measuring position X_C, Y_C, Z_C is known. Figure 5 illustrates a method for determining this relationship. The sensor unit 1 is positioned such that at least three of the reference points 9 are inside its measurement volume. By simultaneously registering the position of the reference points relative to the coordinate system of the scanner unit, and the position of the unit for measuring position relative to the reference points, the information required to calculate the transform between these two coordinates is acquired.

PCT/NO00/00235
08 -10- 2001

Amended Patent Claims

1.
System for detection of the surface geometry of an object (6), comprising a sensor unit (1) with apparatus (2) for local, point by point detection of surface geometry, and a robot unit (4) for moving the sensor unit (1), characterized in that
the sensor unit (1) includes an optical scanner unit (2) for non-touch probing and detection of the surface geometry of the object, and a position measuring unit (3) consisting of a camera-based sensor (7) designed for registering an image of a network (8) consisting of reference points (9) in known positions and for determining the position of the sensor unit (1) in a global coordinate system defined by said network (8) of reference points (9), and that a computing unit (5) is provided and designed for collection of data from the scanner unit (2) and the position measuring unit (3) and for transformation of the data from the scanner unit (2) to relate them to the global coordinate system.

2.
System as defined in claim 1, characterized in that
the robot unit (4) is designed for stepwise movement of the sensor unit (1).

3.
System as defined in claim 1, characterized in that
the network (8) of reference points (9) is on the object, and that
the position for each reference point in the network is known relative to a coordinate system related to the object

4.
System as defined in claim 1, characterized in that
the robot unit (4) is designed to move the sensor unit (1) step-wise over the object (6).

5.
System as defined in one or more of the preceding claims, characterized in that
the scanner unit (2) is chosen from the following group: laser scanner, single-point distance meter, laser-based triangulation sensor combined with camera, triangulation sensor with two-axis scanning laser, triangulation sensor with laser raster projection in combination with camera, sensor based on pattern projection combined with at least one camera.

6.

System as defined in one or more of the preceding claims, characterized in that the robot unit (4) is chosen from the following group: arm-based robot, Cartesian robot, robot with one, two or more degrees of freedom, program controlled robot, real-time position-controlled robot based on registered position of the sensor unit (1) in relation to the object and instruction for movement relative to current position.

7.

System as described in one or more of the preceding claims, characterized in that said camera in the unit (3) for measuring position is a CCD camera.

8.

System as described in claim 3, characterized in that the reference points (9) are holes or depressions in the surface of the object (6).

9.

System as described in claim 3 or 8, characterized in that the reference points (9) consist of so-called "targets" placed on the object (6) or in the mentioned holes or depressions in the surface of the object (6).

10.

Method for detection of the surface geometry of an object (6), including use of a sensor unit (1) comprising apparatus (2) for local, point by point detection of the surface geometry, a position measuring unit (3) to determine the position of the sensor unit in relation to a network (8) of reference points (9) in known positions relative to a global coordinate system, and a robot unit for moving the sensor unit, characterized in the steps of:

positioning the sensor unit (1) such that a region of the surface of the object (6) is inside a measurement volume of the apparatus (2),

optically scanning said region by means of said apparatus (2);

determining by means of said position measuring unit (3) simultaneously the position of the optical scanning apparaus (2) relative to the coordinate system of the network (8), and

transferring data from the scanning apparatus (2) to a computing unit (5) where said data are transformed to the coordinate system of the network (8) and stored.

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11.

Method as specified in claim 10, characterized in stepwise moving of the sensor unit (1) by means of the robot unit (4).

12.

Method for calibration of a sensor unit (1) which comprises apparatus (2) for local detection of a surface geometry, and a position measuring unit (3) to determine the position of the sensor unit in a global coordinate system relative to a network (8) of reference points (9) in known positions, and where the sensor unit (1) is mounted on a robot unit (4) for movement relative to an object (6), characterized in the steps of:

a) positioning the sensor unit (1) such that at least one of the reference points (9) is inside a measurement volume of the apparatus (2), said apparatus capable of optical scanning,

b) determining the position of the reference point (9) relative to the optical scanning apparatus (2),

c) determining by means of the position measuring unit (3) simultaneously the position of the sensor unit (1) relative to the coordinate system of the network (8),

d) repeating steps a-c or b, c until the position of at least three reference points (9) have been determined relative to the coordinate system of the optical scanning apparatus, and

e) calculating a transformation matrix based on data registered by the scanning apparatus (2) and the position measuring unit (3) to describe the mutual relationship.

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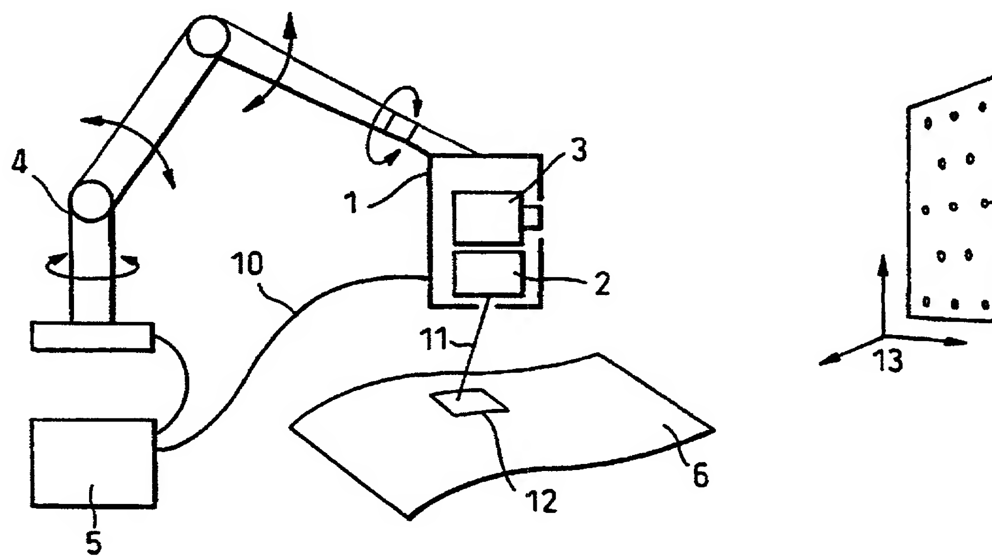
[Continued on next page]

(54) Title: SYSTEM FOR SCANNING OF THE GEOMETRY OF LARGE OBJECTS



(57) Abstract: System for detection of the surface geometry of an object (6), comprising a sensor unit (1) with apparatus (2) for local, point by point detection of surface geometry, and a robot unit (4) for moving the sensor unit (1), in the sensor unit (1) there is included an optical scanner unit (2) for non-touch probing and detection of the surface geometry of the object, and a position measuring unit (3) designed to determine the position of the sensor unit (1) in a global coordinate system defined by a network (8) of reference points (9) in known positions. A computing unit (5) is provided and designed for collection of data from the scanner unit (2) and the position measuring unit (3) and for transformation of the data from the scanner unit (2) to relate them to the global coordinate system. Further, there is present a method for detection of the surface geometry of an object (6), and a method for calibration of a sensor unit (1).

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Fig.1.

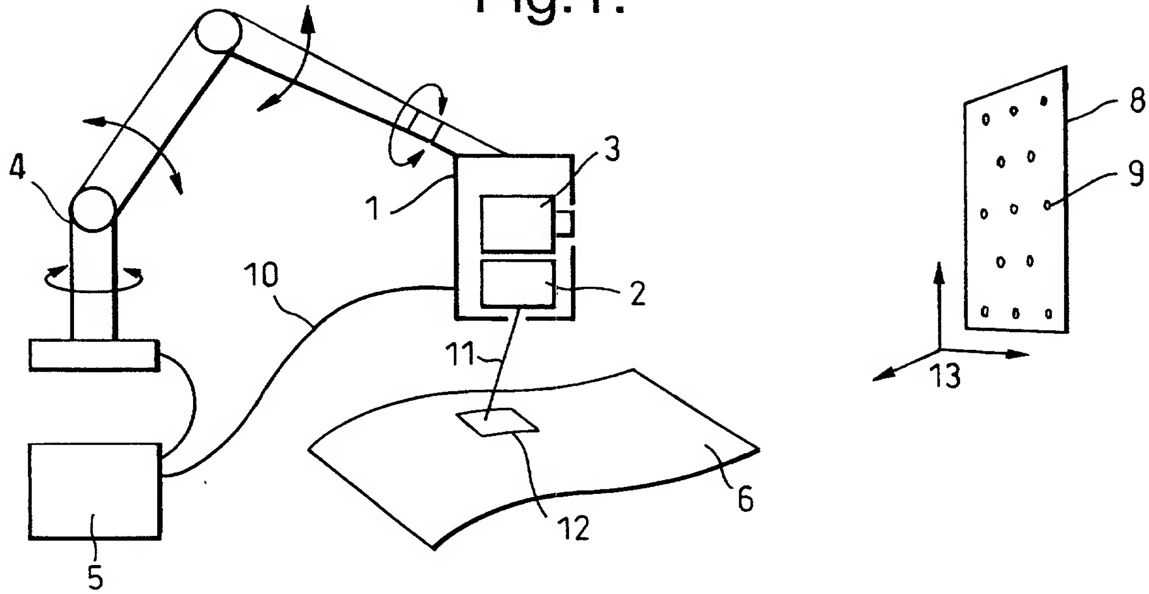


Fig.2.

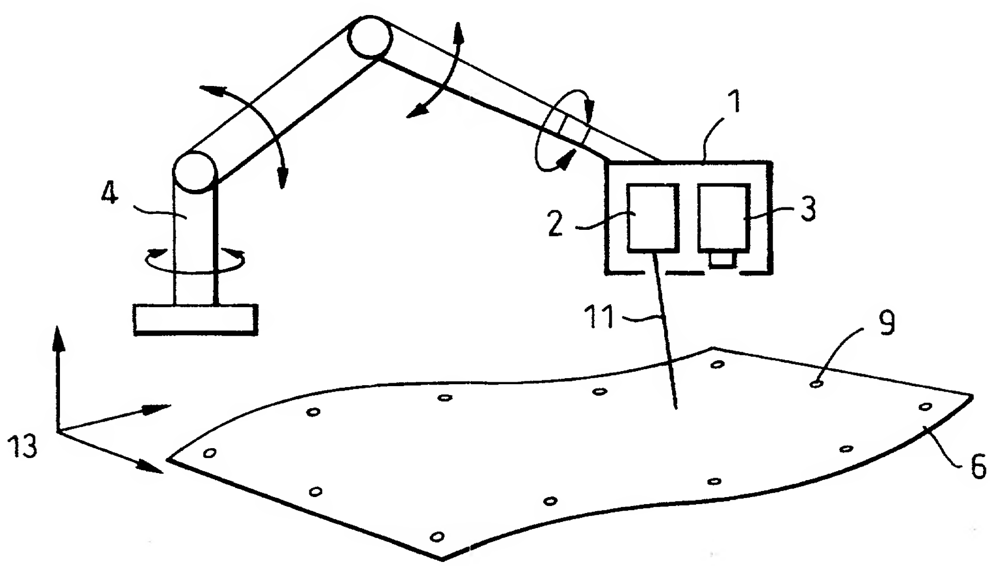


Fig.3.

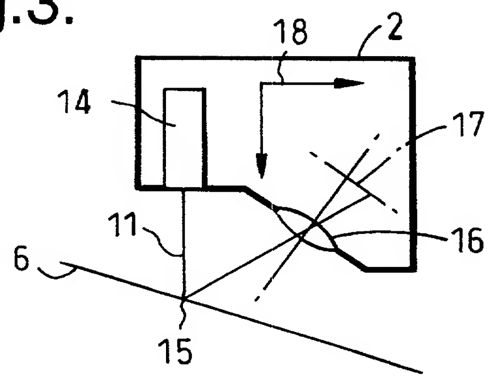


Fig.4.

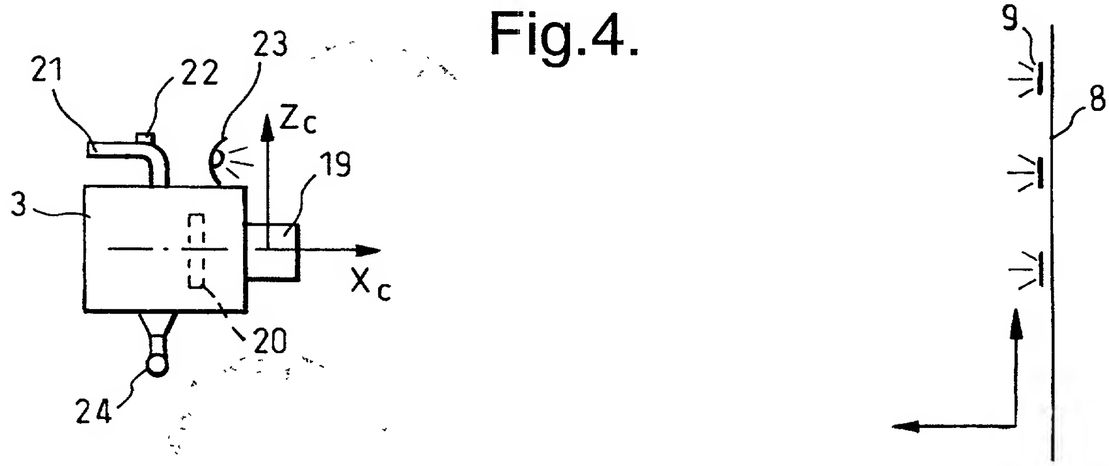
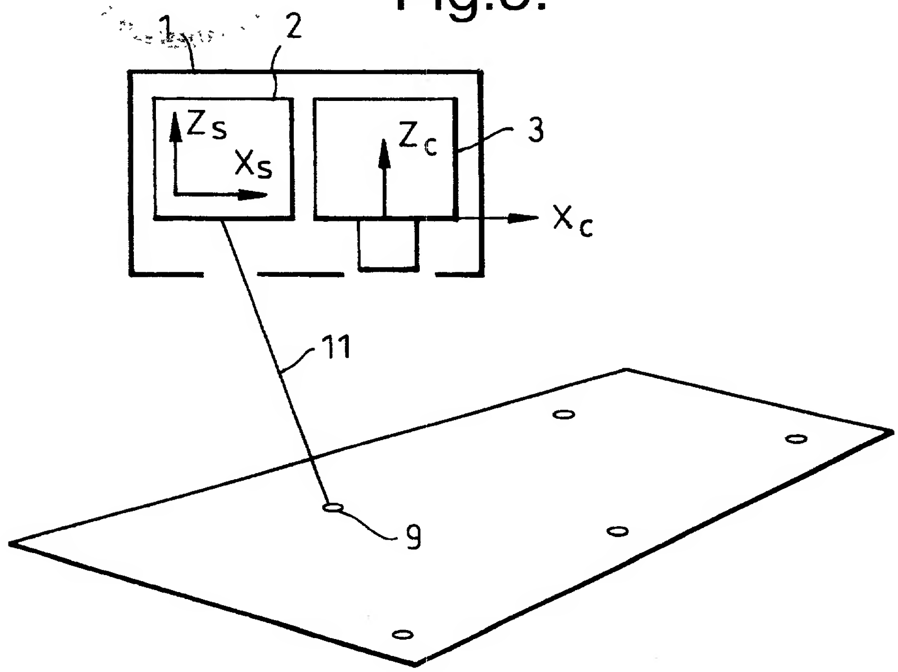


Fig.5.



FOR UTILITY/DESIGN
CIP/PCT NATIONAL/PLANT
ORIGINAL/SUBSTITUTE/SUPPLEMENTAL
DECLARATIONS

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PW FORM

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the INVENTION ENTITLED SYSTEM FOR SCANNING OF THE GEOMETRY OF LARGE OBJECTS

the specification of which (CHECK applicable BOX(ES))

X BOX(ES) → A. ☐ is attached hereto.
→ B. ☒ was filed on January 14, 2002 as U.S Application No. 09/
→ C. ☒ was filed as PCT International Application No. PCT/ NO00/00235 on July 10, 2000
and (if applicable to U.S. or PCT application) was amended on October 8, 2001

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. Except as noted below, I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International Application which designated at least one other country than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International Application, filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority claimed, before the filing date of this application

PRIOR FOREIGN APPLICATION(S)

Number	Country	Day/MONTH/Year Filed	Date first Laid-open or Published	Date Patented or Granted	Priority NOT Claimed
19993446	NORWAY	13 July 1999			

If more prior foreign applications, X box *at bottom* and continue on attached page.

Except as noted below, I hereby claim domestic priority benefit under 35 U.S.C. 119(e) or 120 and/or 365(c) of the indicated United States applications listed below and PCT international applications listed above or below and, if this is a continuation-in-part (CIP) application, insofar as the subject matter disclosed and claimed in this application is in addition to that disclosed in such prior applications, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in 37 C.F.R. 1.56 which became available between the filing date of each such prior application and the national or PCT international filing date of this application:

PRIOR U.S. PROVISIONAL, NONPROVISIONAL AND/OR PCT APPLICATION(S)

Application No. (series code/serial no.)	Day/MONTH/Year Filed	Status pending, abandoned, patented	Priority NOT Claimed

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint Pillsbury Winthrop LLP, Intellectual Property Group, telephone number (703) 905-2000 (to whom all communications are to be directed), and persons of that firm who are associated with USPTO Customer No. 909 (see below label) individually and collectively my attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent, and I hereby authorize them to delete from that Customer No. names of persons no longer with their firm, to add new persons of their Firm to that Customer No., and to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct the above Firm and/or an attorney of that Firm in writing to the contrary.

USE ONLY FOR PILLSBURY WINTHROP

00909

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1-00

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Residence			
	City	State/Foreign Country	Country of Citizenship
Mailing Address (include Zip Code)			

☐ FOR ADDITIONAL INVENTORS see attached page.
☐ See additional foreign priorities on attached page (incorporated herein by reference).

Atty. Dkt. No. P290591
(M#)